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Description of Landsat Thematic Mapper Image of Northern Part of the Paradox Basin and the La Sal Mountains Laccolith Complex

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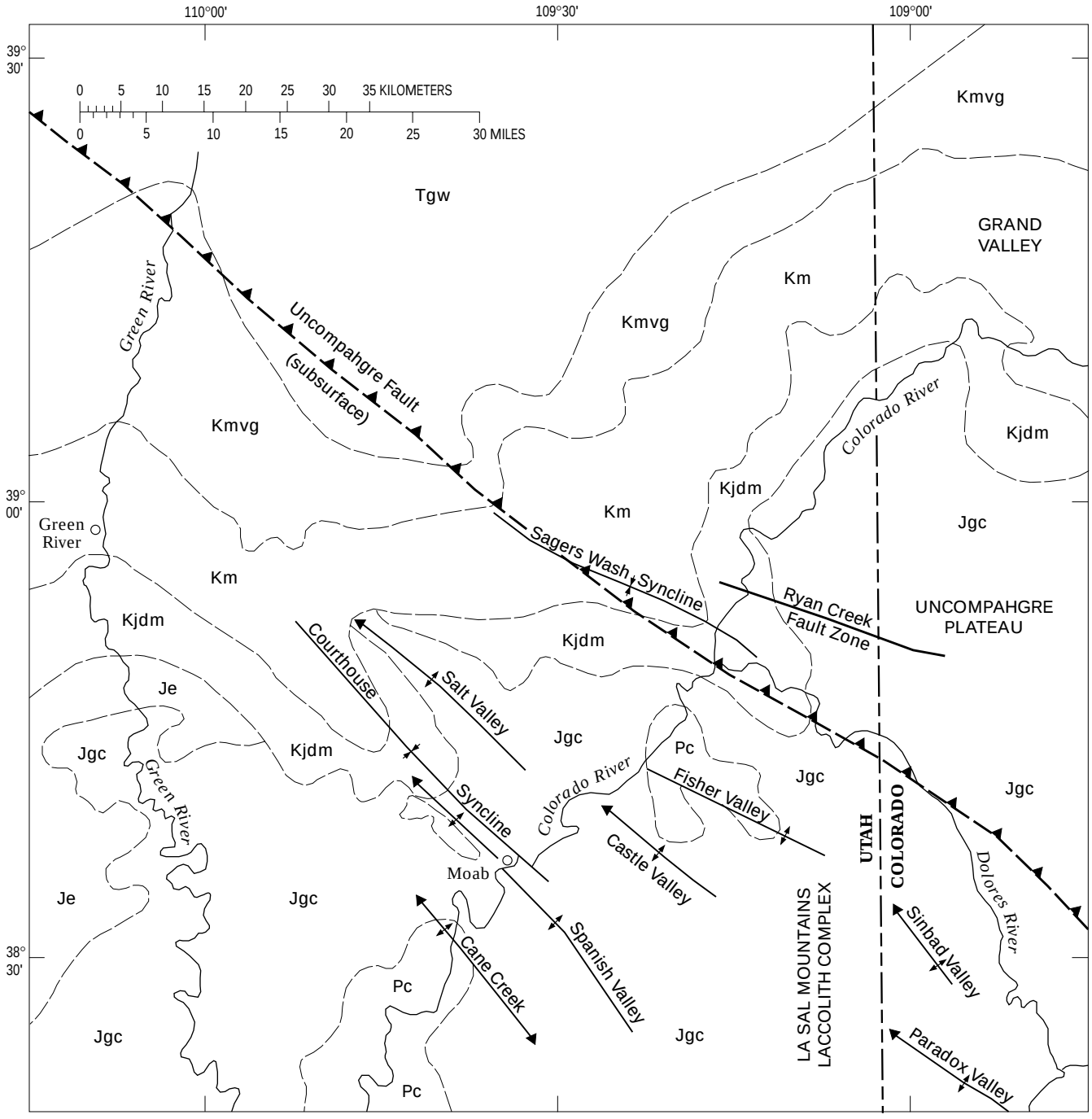
ABSTRACT

A Landsat 5 Thematic Mapper color-infrared composite image highlights the geographic and geologic features of the northern part of the Paradox Basin including the La Sal Mountains laccolith complex. This image depicts the outcrop pattern of Paleozoic, Mesozoic, and Cenozoic stratigraphic units, using color distinctions based on spectral characteristics of individual lithologies. Structures and lithologies, presented in plan view, can be correlated with geologic maps. Anticlinal and synclinal forms, surface faults, domes and collapse structures, major river courses, and intrusive laccolith centers align with major lineaments. The image also yields evidence for the geologic processes of superposition, antecedence, and subsurface salt solution with concomitant valley floor subsidence, all of which have shaped the region.

DESCRIPTION OF IMAGE

Many geographical and geologic features of the northern part of the Paradox Basin are clearly visible on the accompanying satellite image (see frontispiece to this volume). Feature locations are shown in the accompanying sketch map (fig. 1).

The color-infrared composite (CIR) image was acquired by the Landsat 5 Thematic Mapper (TM) on June 14, 1985 (Path 36, Row 33, Scene ID 45047017262x0). The volume frontispiece is a subset of the TM scene. It has 4,834 scan lines and 4,673 pixels per scan line, and it covers an area of 20,000 square kilometers at a resolution of 30 meters per pixel. It has been saturation enhanced, using bands 4, 3, and 2 colored red, green, and blue, respectively, to increase its color density. Saturation enhancement increases color purity from pastel (colors with white added) to vibrant. The TM



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EXPLANATION

Tgw	**Green River and Wasatch Formations (Eocene)**
Kmvg	**Mesaverde Group (Upper Cretaceous)**
Km	**Mancos Shale (Upper Cretaceous)**
KJdm	**Dakota Sandstone (Upper Cretaceous) and Morrison Formation (Upper Jurassic)**
Je	**Entrada Sandstone (Middle Jurassic)**
Jgc	**Glen Canyon Group (Lower Jurassic)**
Pc	**Cutler Formation (Lower Permian)**

Contact, approximately located

Axis of anticline with plunge direction

Axis of syncline with plunge direction

Thrust fault—Sawteeth on upthrown block

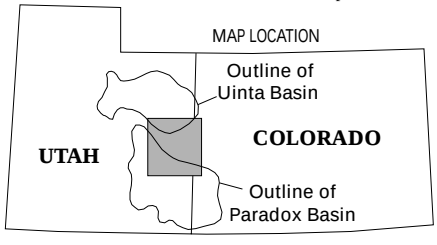

Figure 1 (previous page). Generalized geology of the northern part of the Paradox Basin and the La Sal Mountains laccolith complex. See frontispiece to this volume for color-infrared composite image has been rectified and registered to a Universal Transverse Mercator (UTM) grid, compatible with that used for the USGS 1:250,000 geologic map series. However, because of space restrictions, the image is reproduced here at a scale of only 1:750,000. Crossticks on the image show latitude and longitude coordinates at 30-minute intervals.

LITHOLOGY

Specific lithologies of the northern part of the Paradox Basin (Williams, 1964; Williams and Hackman, 1971; Cashion, 1973) correlate well with the color mapping on the TM image. Shades of blue, green, and yellow are used to identify various sedimentary units. Areas displayed in red delineate regions with abundant vegetation; slightly vegetated regions tend to be lighter in red. White and black areas are clouds with shadows. Snow on the crests of the La Sal Mountains is also mapped as white.

Sparsely vegetated shale, siltstone, mudstone, and marlstone exposures of the Morrison Formation (Upper Jurassic), Mancos Shale (Upper Cretaceous), Wasatch Formation (Eocene), and Green River Formation (Eocene) are mapped in various shades of blue. Shale, siltstone, and mudstone exposures of the Morrison Formation appear as a dark-blue mapped zone that trends east-west through the mid-part of the image, marks the south side of the Grand Valley, forms embayments in the Sagers Wash syncline and the Courthouse syncline, and farther west, passes south of the town of Green River, Utah. Further exposures of the Morrison are present from the La Sal Mountains east into the Uncompahgre uplift, although these exposures are mostly masked (mapped red) by vegetation. Exposures of the Mancos Shale, mapped as light blue, trend east-west through the north-central part of the image, following the Colorado River and the south edge of the Uinta Basin, just north of the exposures of the Morrison Formation, through Green River, Utah. North of the outcrop area of the Mancos Shale, the Wasatch and Green River Formations cover an extensive region and are mapped as purple to dark blue.

Major sandstone units within this CIR image are distinguishable according to the abundance of ferruginous minerals in the rock, using the mapping colors green to yellow. Ferric oxide-bearing red beds, such as the Cutler Formation (Lower Permian), appear as green; less ferruginous sandstones are mapped as green through greenish yellow (Lower Jurassic Glen Canyon Group, Middle Jurassic Entrada Sandstone, and the Upper Cretaceous Dakota Sandstone and Mesaverde Group). Non-ferruginous sandstones and unconsolidated sands are mapped as light yellow to white. The color-infrared composite image translates the visually red color of the Cutler Formation into the bright-green image colors immediately north, northeast, and west of the La Sal Mountains. The Glen Canyon Group dominates the southern half of the image; it includes the Wingate Sandstone and the Kayenta Formation, which are usually dark to light olive green in the image, and the Navajo Sandstone, which appears light yellowish green. The Entrada Sandstone is exposed in the San Rafael Desert, at the far southwest edge of the TM image. It is partly covered by active sand dunes, and appears light yellow to white. Both the Dakota Sandstone, which forms thin hogbacks south of the Mancos Shale, and the sandstone units in the Mesaverde Group, exposed as dip slopes north of the Mancos Shale, are mapped dull brownish olive-green.

STRUCTURE

Structurally controlled geomorphic features are prominent in the TM image, and they clearly show the dominant northwest and northeast trends found within the Paradox Basin. Geomorphic features include salt-cored anticlines and associated synclines, linear features in the clastic rocks, doming around laccoliths, and collapse structures.

Baars and Stevenson (1981), Lee (1988), Friedman and Simpson (1980), and Friedman and others (1994) have mapped a series of northwest-trending lineaments using Landsat Multispectral Scanner (MSS) data. The features that compose these lineaments are visible on the TM image, especially a prominent system of salt-cored anticlines and associated synclines, which formed from late Paleozoic time to the present. One conspicuous example, near the center of the area, is the breached Salt Valley anticline, which is flanked by the Courthouse syncline to the southwest and the Sagers Wash syncline to the northeast. Other principal northwest-trending landforms north of the Colorado River are the Moab anticline, the linear trend of the Green River, and the eastern part of the Grand Valley. Just south of the Colorado River are the Cane Creek, Spanish Valley, Castle Valley, and Fisher Valley anticlines. Farther southeast, beyond the La Sal Mountains, red cultivated fields mark the northwest-trending Paradox Valley anticline, and to the north of it are two other northwest-trending features: the Sinbad Valley anticline and the Dolores River alignment. Also trending northwest are faults and joints produced during Mesozoic and Cenozoic time by tectonic and halokinetic processes, and by valley-floor subsidence over the axial zones of salt-cored anticlines (Hite and Lohman, 1973).

Many of the northeast-trending lineaments represent joints, faults, and other surface fractures (Lee, 1988; Friedman and others, 1994). These linear features are expressed within the present TM image as small discontinuous trends to the northeast. An exception is the Colorado River

lineament, which trends northeast parallel to or coincident with the Colorado River Valley throughout this image.

The La Sal Mountains laccolith complex was emplaced at the intersection of major northeast- and northwest-trending lineaments (Friedman and others, 1994). The La Sal Mountain peaks trend along a line to the northeast, whereas most of the individual laccoliths, as well as the axes of folding in the overlying sedimentary rocks, follow the underlying structural trend to the northwest (Hunt, 1983). The North La Sal Mountain laccolith center, now exposed through erosion, is elongated along the Castle Valley and Paradox Valley anticlines.

PROCESSES

Tectonic, sedimentary, erosional, and igneous processes have shaped the region. Tectonic uplift has created the Uncompahgre Plateau northeast of the tectonic line marked by the Uncompahgre fault, while crustal downwarping has created the Paradox and Uinta Basins. The evolving marine and lacustrine environments have controlled sedimentation of facies ranging from evaporites to sandstone to shale. In this area, the shallow northward regional dip and differential erosion have resulted in a pattern that appears as a younging of the formations from the south edge to the north edge of the TM image area.

Uplift of the Colorado Plateau during the Laramide orogeny has led to downcutting and differential erosion. Antecedent cross-axial drainage is demonstrated by the greater incision of streams and rivers to the southwest (Hunt, 1983), where the Green and Colorado Rivers join. Differential erosion has formed massive sandstone cliffs and mesas to the south and has left the more readily eroded thick shale units exposed in protected valley slopes and bottoms to the north.

The locations of major river channels were controlled by several processes. The Green, Colorado, and Dolores Rivers, as well as the southwest-flowing streams that exhibit a trellis drainage pattern north and east of the Ryan Creek fault zone on the east-central part of the image area, have been locked into position along zones of structural weakness (Maarouf, 1983). These rivers follow deep-seated structures but have local deviations. Locally, the meanders of the Green River have been incised into the Glen Canyon Group (southwestern part of image area); farther north, the Green River's course is horizontally displaced by faulting (south of Green River, Utah). The Colorado River locally flows around the noses of plunging anticlines (Case, 1991). Erosion and downcutting by the Dolores River has breached the Sinbad Valley salt-cored anticline, causing collapse of the clastic rock beds over the anticlinal core and producing vertical walls. Erosion has also exposed the laccolith complex within the La Sal Mountains, stripping back the cover of clastic rock units; this feature is especially prominent on the northeast flank of the domal uplift of the North La Sal Mountain laccoliths.

SUMMARY

The CIR image can be used to visualize, confirm, and supplement features mapped by geologic field methods and photogeology. In addition, many lithologies are distinguishable by spectral color differences, which also sharply outline areas of regional dip, laccolithic doming, and anticlinal collapse.

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